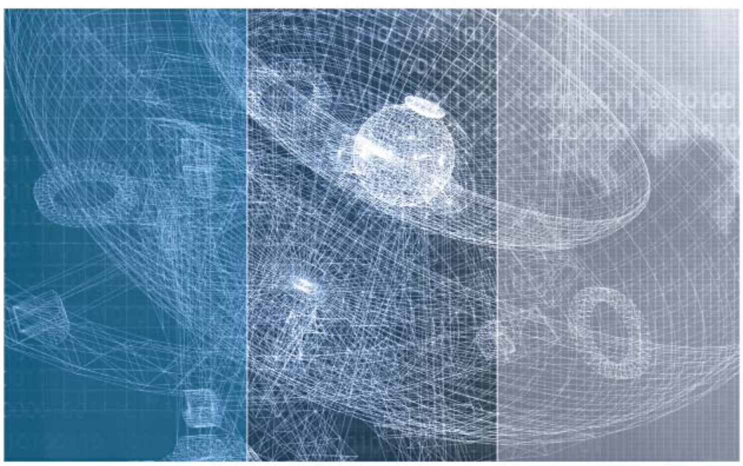
Enabling a multi-service

Creating value from vision



Super Demo 2003

Test Plan and Results

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Introduction »

With the telecommunications market in an unpredictable state over the past few years, service providers have been looking to reduce operating expenses and equipment costs while continuing to offer a high quality service. The need for simultaneous convergence of voice, video, and data networks is increasing the pressure on service providers to build a new infrastructure or modify their existing infrastructure to support these services. The IP/MPLS network offers a very viable solution to this problem by already providing support for these multiple MPLS enabled services. The upgraded network can offer:

- Converged services on a single network while not degrading the quality of the current services.
- Privacy and security that restricts access at the provider edge, thus creating centralized access control to the attachment to each customer premise.
- A more manageable network. Simultaneous updates and remote configurations from a central location save operating costs and decrease the roll out time for adding new customers.
- Increased scalability and interoperability.

With the above advantages, there is also a move toward building these networks with multi-vendor solutions so as to implement best-of breed networks. Seamless interoperability with resiliency and scalability is a requirement in multi-vendor networks. MPLS also enables convergence of legacy and next generation services over a common core. This provides operational benefits for the Provider, reduces the total cost of ownership (TCO), and enables additional revenue from new services.

In an effort to aid the interoperability between vendors and to display the further capabilities of a MPLS network, the MPLS and Frame Relay Alliance has coordinated the "Enabling a Multi-Service Future" Interoperability SuperDemo. Leading up to this demonstration, a "hot stage" interoperability event was held at the University of New Hampshire InterOperability Laboratory (UNH-IOL). To prove the scalable and interoperable service offerings enabled by MPLS, the Alliance built a network to concurrently demonstrate these multiple services over a scalable edge and core network with leading network equipment vendors.

The MPLS SuperDemo »

The 2003 MPLS SuperDemo covered the large number of test scenarios listed below.

- ATM over MPLS based on the Pseudo Wire Emulation Edge to Edge (PWE3) drafts
- Frame Relay over MPLS based on the PWE3 drafts
- Ethernet VLANs over MPLS based on the PWE3 drafts
- Virtual Private LAN Services (VPLS) based on draft-lasserre-vkompella-ppvpn-vpls-04.txt
- BGP/MPLS IP VPNs based on RFC 2547bis
- Fast ReRoute (FRR) support in the core network

This SuperDemo marked the first time that ATM and FR over MPLS have been displayed in a public multi-vendor live test demonstration. It is also the first time that all of these MPLS services have been configured and demonstrated together.

The following companies and products took part in the SuperDemo:

Alcatel	7670 Routing Switch Platform (RSP)
Alcatel	7770 Optical Broadband Exchange (OBX)
Agilent	RT900
Cisco	GSR 12404
Cisco	GSR 12406
Ixia	400T and 1600T
Juniper	M40e
Juniper	ERX 1440
Laurel	ST 200
Marconi	BXR-48000
Marconi	ASX-4000
Nortel	Passport 15000
Nortel	Shasta 5000 Broadband Service Node (BSN)
RADUSA	IPmux
Riverstone	RS 8000
TiMetra	SR-Series Service Router
Vivace	Viva1050
Masergy	InCONTROL Service Control Center
Finisar	In-Line Optical Taps and Splitters

The following devices participated in setting up the core network:

Alcatel	7770 OBX
Cisco	GSR 12406
Juniper	M40e
Marconi	ASX-4000
Marconi	BXR-48000

Of these core devices, the following participated in the fast reroute interoperability tests:

Detour Fast Re-Route	
Alcatel	7770 OBX
Juniper	M40e
Marconi	BXR-48000

Facility Fast Re-Route Participants	
Cisco	12404
Alcatel	7770 OBX
Cisco	12406

To send streams of traffic over the network, the following devices were used as Customer Edge (CE) devices:

Agilent	RT900
Ixia	400 & 1600T
RAD	IPmux

In the actual tests these CE products sometimes emulated PE devices. The RAD IPmux sent TDM over IP traffic to help measure the service quality being offered to the traffic by the MPLS services.

Along with the interoperability testing, the event also included scalability testing of the various services across the core network, including sending real traffic across the large number of VPNs and transport tunnels. The scalability numbers represented realistic values required in today's networks.

The following chart list the MPLS Service Types, the scalability achieved per PE device, and the number of companies participating in each test.

Service Type	Scalability Number achieved per PE	Participating companies with PE devices
BGP/MPLS VPNs	250	11
FR over MPLS	100	6
ATM over MPLS	100	6
Ethernet VLANs over MPLS	100	8
VPLS	1 at UNH, 100 at Supercomm	4

This chart lists each company and product that participated in each service test:

Service Type	Participating companies with PE devices
BGP/MPLS VPNs	Alcatel 7670 RSP Alcatel 7770 OBX Agilent Cisco GSR 12404 Ixia Juniper Networks M40e Juniper Networks ERX Laurel Networks ST200 Nortel Passport 15000 Nortel Shasta 5000 BSN Riverstone RS 8000
FR over MPLS	Agilent Cisco GSR 12404 Ixia Juniper Networks ERX Laurel Networks ST200 Vivace Viva1050
ATM over MPLS	Agilent Cisco GSR 12404 Ixia Juniper Networks M40e Laurel Networks ST200 Vivace Viva1050
Ethernet VLANs over MPLS	Agilent Cisco GSR 12404 Ixia Juniper Networks M40e Juniper Networks ERX Laurel Networks ST200 Riverstone RS 8000 Vivace Viva1050
VPLS	Agilent Ixia Riverstone RS 8000 TiMetra SR-Series Service Router
P Router	Cisco GSR 12406 Marconi ASX-4000 Marconi BXR-48000 Alcatel 7770 OBX

Test Scenarios »

The test plan was created by a group of individual contributors from the following organizations: Agilent Technologies, Laurel Networks, TiMetra, Tenor Networks, University of New Hampshire Interoperability Lab, European Advanced Network Testing Center (EANTC), Netplane Systems, Avici Systems and Metanoia. The test plan was then discussed with all the participants in the event to ensure that the test scenarios were suitable.

Three MPLS service scenarios were tested in isolation and then implemented across a core MPLS network.

The services include:

- Layer 2 point to point VPN service to transport services:
  - ATM (Cell and AAL5 modes)
  - Frame Relay (Transport mode)
  - Ethernet (Port and VLAN modes)
- Virtual Private LAN service (VPLS)
- BGP/MPLS VPN service

In addition, Fast Reroute was tested in the MPLS core.

Layer 2 VPN Services

Layer 2 Virtual Private Networks are established by one or more point-to-point pseudo-wire (PW) tunnels carrying arbitrary layer 2 traffic over a core network running MPLS. The goal of PW tunnels is to form a direct path through the core network as an alternative to a leased line. The transport offered may be ATM, Frame Relay or Ethernet. In all cases, the required functions at the provider edge router (PE) are:

- MPLS signaling to establish layer 2 tunnels and to define their parameters
- MPLS data encapsulation to forward service-specific data in the appropriate way through the MPLS backbone
- Provision of service-specific interfaces towards the customer edge

Encapsulation types that were tested include Ethernet (port based and VLAN), Frame Relay, and ATM (transparent mode, cell mode and AAL5).

In all the cases the core router has to swap the top MPLS label and transparently transport these services on a scalable basis through the MPLS core network.

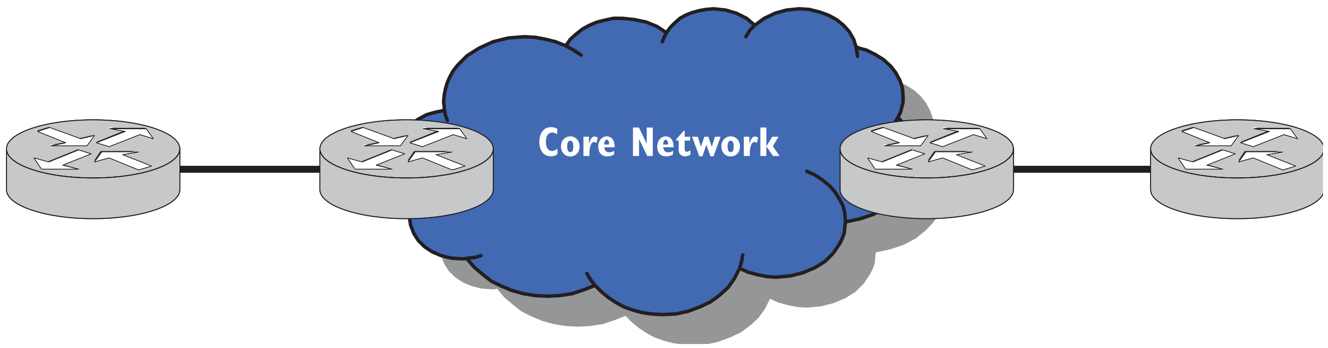

Figure 1: Pseudo-wire emulated tunnels form layer 2 VPN

Virtual Private LAN Service (VPLS)

Virtual Private LAN Service (VPLS) is a class of VPN that allows the connection of multiple sites in a single bridged domain over a provider managed IP/MPLS network. All customer sites in a VPLS instance appear to be on the same LAN, regardless of their location. VPLS delivers a layer 2 broadcast domain that is fully capable of learning and forwarding on Ethernet MAC addresses. Standard learning, filtering and forwarding actions, as defined in the IEEE 802.1 specifications, are required when a logical link state changes.

As with MPLS/BGP VPN technology, VPLS is a point to multi-point service. The difference is that at the connection between the PE and CE devices have no IP protocol interaction. To simplify operation, the connection behaves in the manner of an Ethernet Bridged connection.   The customer views the service provider network as a set of Ethernet switches.

The core network consists of transit LSRs, whose function is to provide PE to PE connectivity over an MPLS core.

The four participant devices were connected across the core topology. They signaled a full mesh of VPLS tunnels. It was verified that layer 2 Ethernet traffic could be transported across the core in a transparent manner.

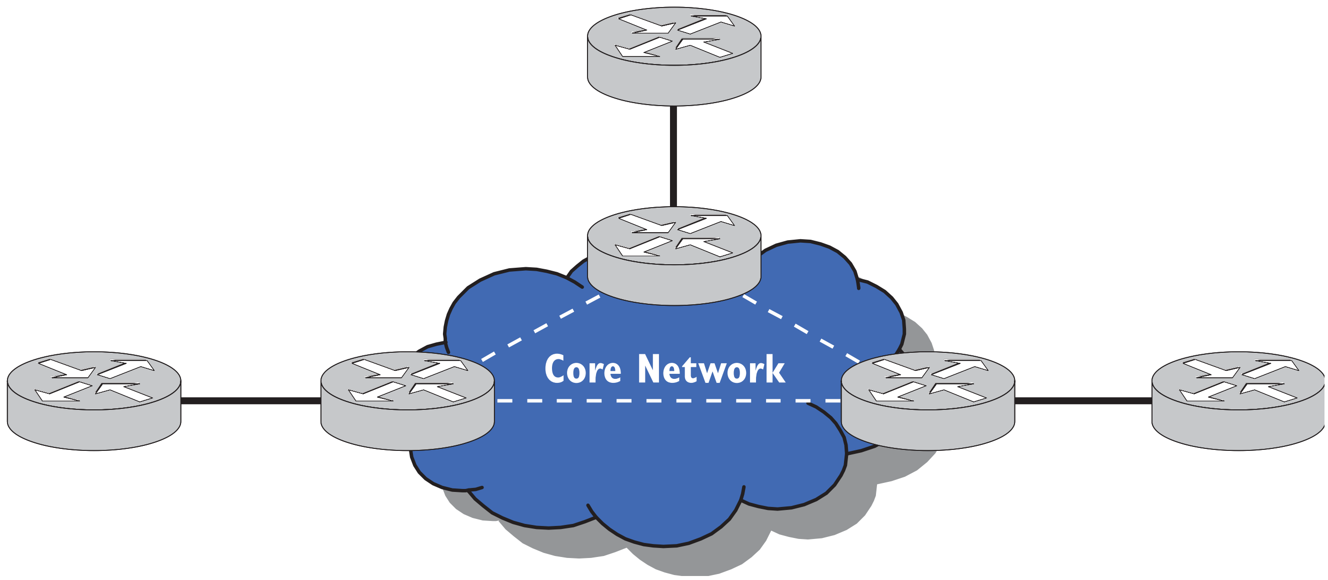

Figure 2: Multi-site connectivity that characterizes layer 3 VPNs and VPLS

Layer 3 VPN Services

Layer 3 BGP/MPLS IP VPN based on RFC 2547-bis services are established through a routing interaction between the customer edge (CE) and provider edge (PE) routers through a core consisting of 'P' routers. The transport offered is multi-site IP connectivity over a core network running MPLS. BGP is then used by the PE routers to exchange the routes of a specific VPN among remote PE routers that are attached to that VPN. In this model, the routes for each VPN remain separate and secure. If a CE from a specific VPN is not attached to a PE, that PE does not obtain the routes for that VPN. Routes within that VPN are distributed only to the PE and CE routers associated with that VPN.

Fast ReRoute

Fast Reroute technology can provision guaranteed VPN services within an MPLS network. An extension to traffic engineering known as Fast Reroute is a newly developed MPLS application (work in progress, still in draft form). Fast Reroute is a link and node protection mechanism to minimize the packet loss during a label-switched path (LSP) failure by rerouting traffic onto a backup LSP. The primary and backup LSPs are signaled using an optional extension to the Resource Reservation Protocol with Traffic Engineering extensions (RSVP-TE).
There are two Fast Reroute modes:

- Facility (Bypass) and
- Detour.

Both offer distinct advantages and disadvantages, but previous fast reroute related drafts have not accounted for interoperability between the two modes. The most recent IETF draft for fast reroute, draft-ietf-mpls- rsvp-lsp-fastreroute-01(work in progress) provides guidelines to develop the ability for either draft to interoperate while maintaining the advantages of both modes.

Routers in a network supporting MPLS fast reroute take different roles:

- PLR - Point of Local Repair: Head-end label switch router of a backup tunnel (LSP) that is also a label switch router along the primary tunnel (LSP); responsible for switching to the backup path in the case of a failure or to restore the primary path.
- MP - Merge Point: Tail-end label switch router of a backup tunnel (LSP) where the backup path rejoins the protected primary tunnel (LSP); responsible for merging traffic arriving on the backup and primary path.
- Backup Mid-Point: Mid-Point label switch router along the backup path; takes a passive role.

In the testing at this event, the Detour Fast Reroute and Facility Fast Reroute technologies were tested and proven on a network with multiple VPN technologies and traffic passing between the established VPNs.

MPLS Network Implementation »

The demonstration at Supercomm 2003, June 3rd - June 5th, 2003 brought together twelve equipment manufacturers to hold the world's most stable multi-vendor, multi-service MPLS network test.

The demonstration consisted of a core that executed both the facilities backup and the detour methods of Fast-ReRoute. The edge devices demonstrated the different types of service that are available on current products such as: Layer 2 VPN service, VPLS services, and Layer 3 BGP/MPLS IP VPN services. Ixia and Agilent router emulators were connected to each of the PE routers to emulate CE connections running protocols and passing traffic through the core network.

The MPLS network consists of a core of OC-48c POS and OC-12c POS connections. Gigabit Ethernet provides redundancy at the edge and connects the PE and CE routers. The CE emulators are connected to the PE devices and pass traffic through the LSPs that traverse the network.

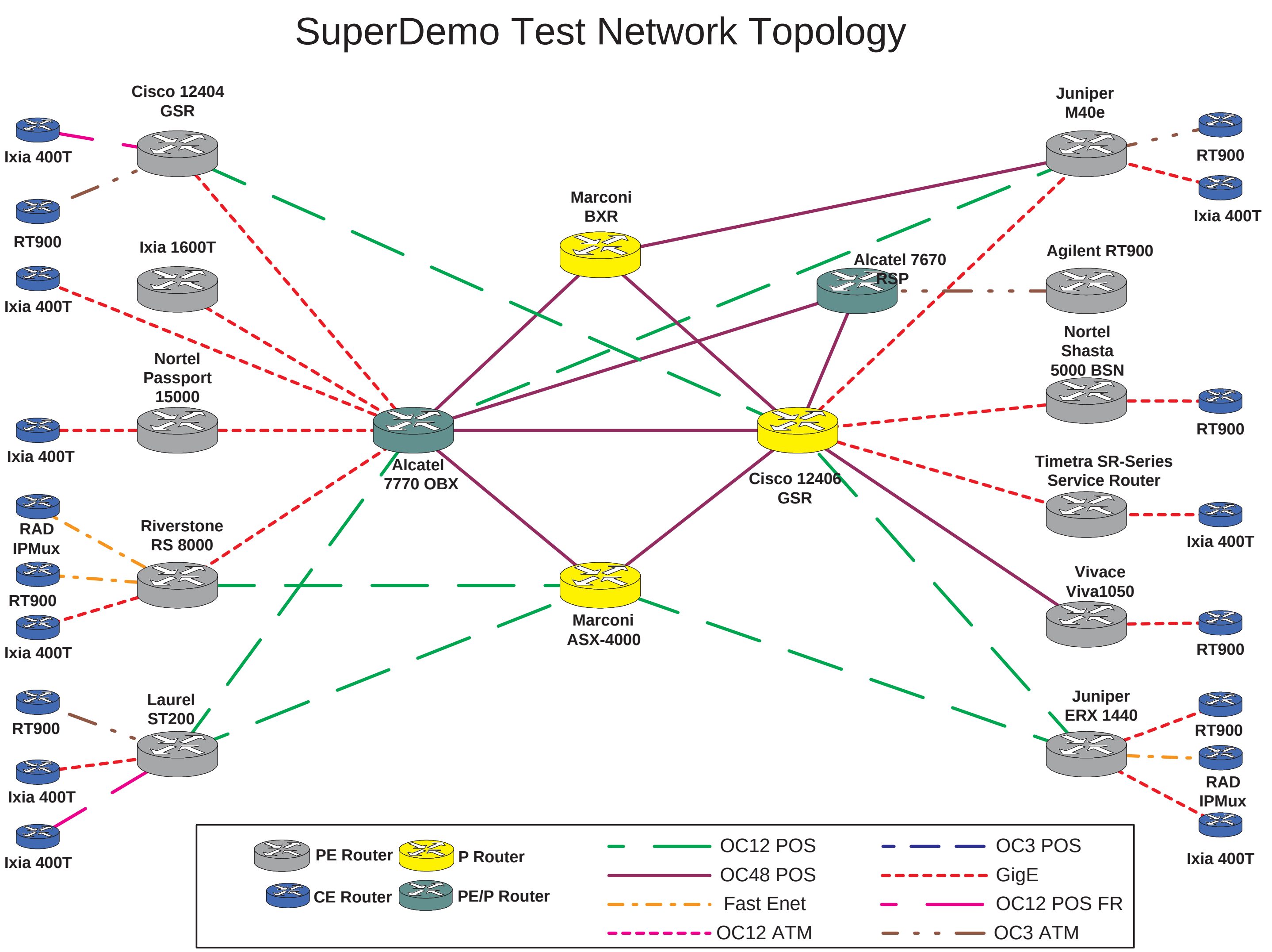

Figure 3: The Topology

Qualification through Hot-Staging

Rotations were run in which Provider Edge (PE) routers were paired point to point to isolate interoperability issues in a controlled network environment. These couplings were rotated for full interoperability coverage. The three areas of test examined each of the MPLS service types that were demonstrated in the final network topology.

The core network was simultaneously built with the transit routers and fast reroute was enabled. When connectivity was confirmed in the core, the analyzer vendors and PE routers setup LSPs across it to confirm functionality.

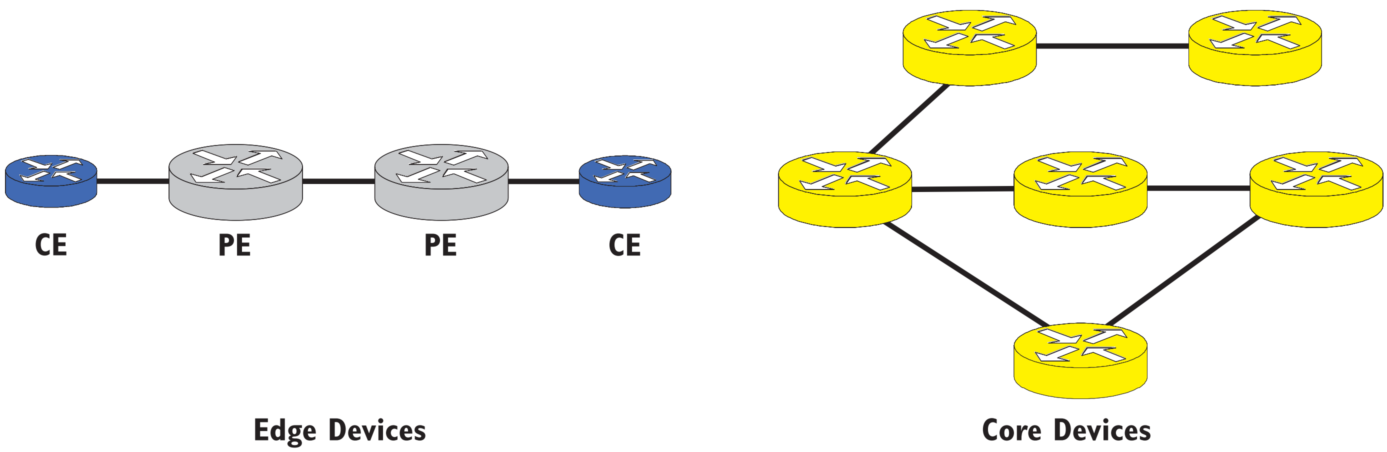

Figure 4: Qualification through Hot-Staging

As the testing of edge services completed and all interoperability issues were isolated, the PE vendors were connected into the network core devices. The analyzers were connected as the CE routers to each PE. The testing of MPLS services was then repeated across the core network. Many LSPs were then created across the core to demonstrate a more realistic network scenario and traffic was passed over each of the LSPs from the router emulator CE devices.

Final Test Results »

The maturity of any networking protocol relies on interoperability testing activity, such as this event, to help identify issues and further refine the specifications so that practical implementations can be achieved. Throughout the intensive nine day MPLS services interoperability event a variety of successes were reached defining an important milestone in the evolution of MPLS technology.

Several issues were also identified during the testing. Below is a summary of those findings. The objective of this list is to make the vendor and service provider community aware of the multi-vendor aspects of this suite of protocols. Some recommendations have been provided as possible ways for resolving these issues to achieve the maximum interoperability. This document will also help those who did not participate to ensure that these issues do not surface in their products. As with other interoperability events in the past, the participants found and fixed issues, improving their products as part of the process.

The documentation of these issues will save resources for both service providers and vendors and will guide in future product development and network deployment.

Issue	Description	Temporary Solution	Recommendation
PPP link connection issues	Various aspects of PPP negotiation failed including the network link control protocol and the MPLS control protocol.	Resolution not possible in some cases, in others unnumbered links were configured at the PPP layer and static IP addresses were assigned to the interfaces.	Document the issues and update software with the proper fix.
LDP Init message	For Ethernet ports, the optional parameters were set at the interface level to a non-zero value. A zero value was expected.	The software was updated to accept a non-zero value in this field.	Non-zero values representing Ethernet interfaces are undefined by the specification and should be addressed by the standards committee.
Logical Interface Handle (LIH)	Logical Interface Handle set to zero in the Resv messages. For MPLS this field should reflect the LIH received in the Path messages.	Resolution not possible.	Document the issues and update software with the proper fix.
Node ID and Interface ID	The base LDP protocol used the node ID and the layer 2 LDP extensions used the interface ID. The link partner did not accept this message structure.	The software was updated to send consistent addresses.	Use Node ID and Interface ID consistently in LDP signaling.
Host Address Length	An assumption of the length of a host address without processing the "Host Addr Len" field in the FEC TLV caused a discard in the LDP frames.	Resolution not possible.	Process and parse based on the "Host Addr Len" field defined for the FEC TLV in RFC 3036.
Reservation Style	Reservation Style supported by equipment is inflexible: FF only or SE only resulting in LSP setup failure.	No resolution possible where the PE routers supported only one of the filter styles and were strict about message contents.	RFC 3209 states that the received determines the reservation style, which should be accepted by the sender.
LDP Label Space	RFC 3036 does not make it mandatory to use platform-specific label space for Ethernet interfaces.	The software was updated to include label space for Ethernet interfaces.	Document the issues and update software with the proper fix.
U bit set to one	When a vendor specific TLV was transmitted, a notification message was sent from the link partner indicating a rejection.	The software was updated to ignore TLVs with the U bit set.	According to section 3.6.1.2 of RFC 3036, an unknown message with the U bit set to one should be ignored.

Conclusion »

At Supercomm 2002, June 2002 in Atlanta, the MPLS Forum conducted the world's largest multi-vendor interoperability demo to date. It was stated and proven that MPLS had come a long way from the beginnings in 1997. Our theme last year, and what we highlighted in the live demo, was MPLS is *Ready for Revenue*. In Paris February 2003 the MPLS Forum, with EANTC and the MPLS World Congress, continued to demonstrate Layer 2 and Layer 3 VPN services and for the first time demonstrated a public test of multi-vendor Fast ReRoute interoperability.

At Supercomm 2003 we find that MPLS has continued to progress in standards development, vendor deliverables and carrier deployments, and that MPLS as a technology has undergone many significant developments since previous demonstrations. At Supercomm 2003, the MPLS/FR Alliance SuperDemo is the worlds most advanced and comprehensive live test of multiple MPLS services operating concurrently across a multi-vendor MPLS network.

For carriers to stay competitive in today's market conditions they need to improve end-user service offering, reach into new markets, and be very conscious of costs, capital expenditures and profits.

Some of the requirements to stay competitive are:

- Offer products and services at a lower cost: lower operating expenses and equipment costs; this is passed on to customers.
- Offer products and services at a higher quality: IP network services are now offered in a more reliable and secure manner.
- Innovate new flexible features: different service options allow a service provider to offer customers a choice of Layer 2 or Layer 3 VPN services that are tailored to their needs.
- Increase speed of reaction time to customer demands: provisioning and manageability is simplified, thus these new services are deployed significantly more quickly.

This year's demonstration proves that the MPLS multi-service future is ready now. Comprehensive VPN technology service offerings were tested successfully as interoperable among multiple vendors, proving that MPLS is ready to help carriers meet their goals. The standards are stabilizing, the products are shipping and MPLS is truly enabling a multi-service, multi-vendor future TODAY.

About the MPLS and Frame Relay Alliance

The MPLS and Frame Relay Alliance is an international industry organization of 60 members, advancing the recognition and acceptance of MPLS and Frame Relay technologies in the global telecom industry. The Alliance is driving worldwide deployment of multi-vendor MPLS and Frame Relay networks, applications and services through interoperability initiatives, implementation agreements and educational and marketing resources and programs. http://www.mplsforum.org

About the UNH InterOperability Laboratory

The UNH InterOperability Laboratory (UNH-IOL), as part of the University of New Hampshire (UNH) is a non-profit organization consisting of 15 different testing consortiums, each focusing on building an interoperable solution in a different network technology field. More than 200 companies worldwide are members of the UNH InterOperability Laboratory. The test solutions that are created at the UNH-IOL offer a unique set of methods to increase interoperability through protocol operations, signaling, point-to-point and multi-system scenarios. http://www.iol.unh.edu

Explanation of Tested Features and Protocols

MPLS

Multi-Protocol Label Switching (MPLS) is a method to provide virtual circuit provisioning over multiple network technologies. These virtual circuits, or label switched paths (LSPs) define network paths over which traffic flows. Traffic that transverses the LSPs is labeled for differentiation. This technology allows seamless interworking between Frame Relay, ATM, Packet over SONET and Ethernet networks. MPLS also allows the path determination to be made at the network ingress, thus Traffic Engineering can be used to solve congestion and improve network throughput.

Frame Relay

Frame Relay is a Wide Area Network (WAN) technology that connects a number of LANs together through leased lines or connects a site to the public internet. The first widely deployed packetized WAN solution, Frame Relay is still very popular.

ATM

Asynchronous Transfer Mode (ATM) is a packetized WAN technology with a similar purpose to that of frame relay, but with additional QoS and traffic shaping capabilities. More expensive as a service, ATM is used by larger enterprises that need the additional functionality.

VLAN

Virtual Local Area Network (VLAN) technology is a method of creating multiplexing LAN segments on the same layer 2 topology. The network Bridges have a mechanism of tagging the traffic and each VLAN acts as a separate LAN instance.

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